The Social Dimension in Ecosystem Management: Strengths and Weaknesses of Human-Nature Mind Maps

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Abstract

The theoretical underpinnings of various analyses of the social dimensions of ecosystem management are closely related to our mental models of human-nature relations. This article presents examples of eco- and anthropocentric, interdisciplinary and complex system mind maps of human-nature relations. It shows that the interpretation of the social dimension in ecosystem management in each mind map advances the study of human-nature relations in a particular way. However, the dysfunctional reductionism of eco-and anthropocentric mind maps and the weak capacity of interdisciplinary mind maps to analyse intersystem and cross-scale linkages is only overcome by complex system approaches. Different types of complex systems mind maps are found capable of comprehensively operationalising the social dimension of ecosystem management for monitoring purposes and also of linking a variety of knowledge types in integrative analyses to support resilience-oriented management. The participation of system stakeholders in transformative and adaptive transdisciplinary work is central in these endeavours.

Keywords: *ecosystem management, social dimensions, human-nature relations, mind maps*

Introduction

Mind maps are pre-analytic ideas or high generality mental constructs. This paper explores the variety of mind maps of the human-nature relation which form the conceptual bases for the diverse treatments of the social dimension in ecosystem management.

Early formal definitions of the term ecosystem excluded Homo sapiens, limiting themselves to the ecology of non-human species (Tansley 1935; Machlis and Force 1997). Subsequent definitions of ecosystems transcended the limits of biological ecology and moved on to questions of how humans live with their environment and with each other (Golley 1993).

Following controversies about its 'resourcist' or bio-centric origins and tendencies (Grumbine 1994; Larkin 1996), ecosystem management is now widely recognised as "an integrated approach to management that considers the entire ecosystem including humans. The goal... is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need" (McLeod et al. 2005, 1). Moreover, social sustainability is now understood as an integral component of the overall goal of ecosystem sustainability. However, there is less agreement on what constitutes social sustainability as such. Serbser (2004) argues that little consensus has been achieved on "the question of which criteria we apply to reach an understanding about social sustainability... What is it that should be shaped and maintained?" (Serbser 2004, 11, translation M.G.).

In the ecosystem management context, this question focuses our attention on the human-nature relation. An identification of the social factors which affect human-nature interactions is required as the foundation for a comprehensive, normatively transparent and operational definition of the social dimension in ecosystem management. Such a definition should be applicable across natural and historical conditions and scales, from the human individual to the social system (Becker and Jahn 1999; Empacher and Wehling 2002; Berkhout el al. 2003; Serbser 2004; Fischer-Kowalski 2004). As groundwork towards a better analytical framework for conceptualising the social aspects of ecosystem management, this paper compares alternative concepts of the human-nature relation.

Major Mind Maps

Following Schumpeter's work of 1954, Costanza (2000) emphasizes the importance of a 'pre-analytic vision' of the world and its major problems. Such intuitive visions can be distinguished from more analytical conceptualisations which are better described as 'high generality conceptual models' (Costanza et al. 1993). This author defines both pre-analytic visions and high generality models as 'mind maps' and examines a range of mind maps on the human-nature relation as encountered in academia, among ecosystem and natural resource managers and decision-makers as well as society in general. It is assumed that the location of the social dimension on different human-nature mind maps affects the perception of its function and potential. This means that our mind maps "...determine the data that we collect, the questions that we consider 'interesting' and the ways in which we change our views of the world to accommodate new results" (Cumming and Collier 2005, 5). The article distinguishes eco-centric, anthropocentric, interdisciplinary and complex systems mind maps of the human-nature relation as outlined in the following sections and distinguishes their inherent conceptualisations of the social dimension of ecosystem management.

Eco-centric Mind Maps

Where the social system is considered part of the natural system and/or social needs as subordinate to ecosystem requirements, mind maps of the human-nature relation are eco-centric. This review differentiates between absolutely and moderately eco-centric mind maps.

Absolute eco-centrism treats humanity as 'just another species' with no higher value attached to its needs and priorities. It assigns moral rights and values to both organisms and ecological systems and processes independent of their role for humanity. Moderately eco-centric models from biological ecology, environmental economics and related disciplines view the human-nature relation in terms of human-induced effects which degrade an otherwise 'pristine' nature. Proponents of this view advocate the control of adverse anthropogenic drivers.

The 'web of life'

At the absolutely eco-centric end of the debate is the 'deep ecology' model. The Norwegian philosopher Arne Naess coined the term 'deep ecology' in 1973. Some of its philosophical origins lie with Spinoza, who argued that nature includes all existence, the conscious and self-conscious, as well as the mechanical and the organic and that humanity is part of nature without any special position. In this tradition, deep ecology emphasizes the intrinsic value of all life forms and views human beings as just one more component of the web of natural life. Proponents aim for an economic, technological, and ideological/cultural transformation in which human quality of life is disassociated from the consumption of nature and where respect for the ecosphere takes precedence over individual and collective human needs (Lovelock 1979). Deep ecology is profoundly critical of the instrumentalisation of nature for human purposes implicit in anthropocentrism and emphasizes the organic unity of all forms of life and life-supporting processes.

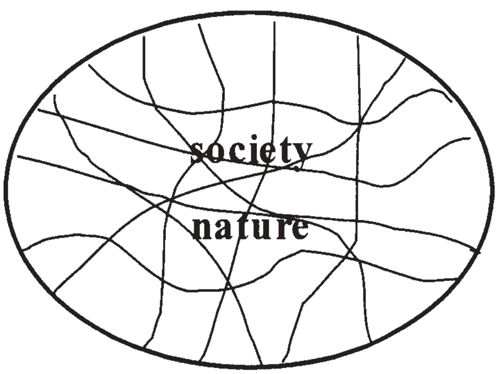

Figure 1. The web of life.

For deep ecologists, the social dimension is part of a single 'web of life' which symbiotically connects human and non-human species into an organic whole and contains the potential for harmonious, sustainable human-nature relations. Figure 1 illustrates this. This means that concern for nature is itself part of nature. In his writings on 'an ecological approach to being in the world' (Naess 1987, 1995) emphasizes human psychological and spiritual connectedness to nature, suggesting that if the human sense of 'self' is widened and deepened, concern for nature logically and 'naturally' ensues. Fox (1990) suggests that this occurs without the need for moral exhortations, but rather as a consequence of a 'this-worldly' realization of an expansive sense of self which embraces a concern for non-human beings. However, many deep ecologists consider that only traditional societies are endowed with the ecological knowledge required to sustain human-nature relations and are deeply pessimistic about modern societies' prospects in this respect. This is similar to the colonial image of the 'noble savage' which idealises the virtues of traditional 'organic' human-nature relationships. The protection of traditional forms of life and of their ecological knowledge systems is indeed a central recommendation of the deep ecology school of thought. Such insistence on traditional modes of life implicitly rejects social-ecological transformations which promise material improvement for marginalized rural populations. Eden (2001, 80) and Diegues (1998) cite cases from Canada, Australia, Mexico and Brazil, where the categorisation of aboriginal and other groups as 'natural' people has rendered these populations invisible as stakeholders in environmental management. These authors criticise the deep ecology perspective for leading to increased social and economic marginalisation of already disadvantaged human populations.

The deep ecology mind map also influences contemporary thinking about human-nature relations in industrialised societies by advocating the rediscovery of mental and spiritual connectedness with nature in modern life (Gerdes 2005).

Divested of the reductionism involved in defining the human-nature relation as either traditional (and therefore natural) or as part of modernity (and therefore destructive) and of its often patronising approach to traditional people's aspirations, the 'web of life' mind map is at the core of the influential contemporary vision of a planetary transformation of social values towards peace, freedom, development and environmental sustainability, which includes "...a deep awareness of ... connection to one another, future generations and the web of life" (Raskin et al. 2002, 45). By locating humanity within nature, the web-of-life mind map — with its roots in deep ecology — takes a conceptual leap which sociology long failed to achieve. This has opened the path for new types of interdisciplinary research and a constructive engagement of the social sciences with the relations between humanity and nature, for instance in the human ecology and social-ecological systems analysis fields (Glaeser 2004; Berkes et al. 2003).

Thus, in his more recent work, the population biologist Paul Ehrlich argues that the cultural evolution of the human being (who, in the biological tradition, he describes as 'a very smart, language-possessing animal with a need for food, sex and security... that lives in a vast diversity of habitats and that has certain constraints on its perceptual systems and on its mental abilities...in relation to environmental change') (Ehrlich 2002, 32-33) is essential for a positive transformation of the human-nature relation. Positive cultural evolution will, however, depend on the recognition of human embeddedness in nature (Jones 1990), the central concept of the web-of-life mind map.

'Pristine-nature-and-society' with Anthropogenic Drivers

The 'pristine-nature-and-society' mind map (Figure 2), portrays society as embedded within nature but as a conceptually separate entity. It sees social needs as subordinate to the requirements of nature. It thus fits our category of ecocentric mind maps. However, as it conceptualises society as separate from nature, the 'pristine nature and society' mode of thinking contrasts strongly with the holistic 'web of life' concept. This mind map assumes an original 'natural' state of ecosystems, untouched by human impacts, as the ideal situation. Human interactions with nature are conceptualised exclusively in terms of 'social impacts' on nature and invariably seen as detrimental. From this perspective, Hannah et al. (1994) categorise global ecosystems in terms of their degree of human disturbance and find that 'natural habitat has been *replaced* by human activities' (ibid., 246, emphasis M.G.) in over half of all habitable regions on earth.

This idea of a divide between pristine nature on the one hand and society on the other, which has been readily adopted by biological ecologists (e.g. Pomeroy and Alberts 1988; Likens 1992), has some serious shortcomings. It reduces a reality of complex social dynamics with linkages of various types and at various scales to a simplistic, linear impact model. In interdisciplinary research practice, this has promoted a 'false dichotomy' between 'science' and 'social data' (Endter-Wada et al. 1998; Glaser et al. in print). The natural sciences are encouraged to investigate 'natural' dynamics, as if human-induced ecosystem dynamics were only temporary disturbances which need to be controlled (Cormier-Salem 1999) — a 'managerial' task delegated to those engaged in 'social investigation.' The term pure research (Grundlagenforschung) tends to be applied exclusively (and in this author's view erroneously) to natural science research in the framework of this increasingly dysfunctional conceptual separation of pristine nature and society. Archaeologists who produce evidence of ecological change resulting from pervasive human-nature interactions in prehistoric times argue that pristine nature only existed in pre-human times so that the conceptual separation of society from nature is inappropriate for the 'anthropocene.' The widespread evidence of mutually formative human-nature interactions in even the most remote natural environments (Pretty 2002) demonstrates that the separation of society and nature in the 'pristine-nature-versus society' mind map does not provide a basis for constructively addressing the interconnections between humanity and nature. The fact that the originally archaeological term 'anthropocene' passed into general scientific usage over recent years demonstrates growing consensus on this point (Kremer et al. 2005; Reid et al. 2005).

The 'pristine nature and society' mind map remains influential nonetheless. It conceptualises the degradation of formerly 'pristine' natural ecosystems as caused by the negative impacts of 'anthropogenic drivers' as depicted in Figure 2. Population, technology and affluence are among the most important commonly identified anthropogenic drivers.

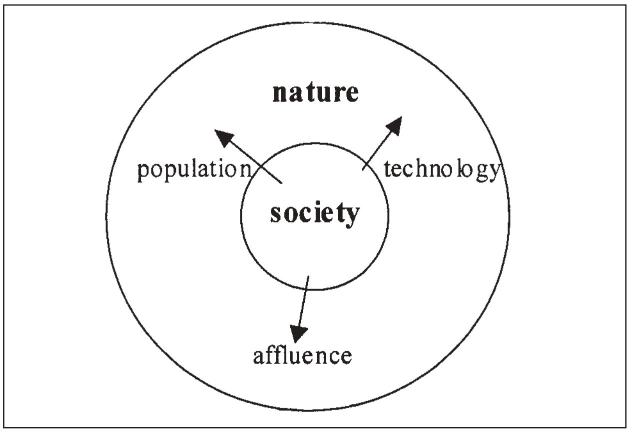

Figure 2. Pristine nature and society with anthropogenic drivers.

Among these, human population size has, in the Malthusian tradition, long been defined as the major social variable to be addressed for the sustainable management of nature (Hardin 1968; Ehrlich 1968, 1991; Pomeroy and Alberts 1988; Daily and Ehrlich 1992). Despite encouraging findings on the adaptability and innovative potential of resource use systems under conditions of demographic growth (Boserup 1965; Krause et al. under review), demographic growth has been interpreted as an entirely negative anthropogenic driver of ecosystem change, in particular by biological ecologists (Likens 1992; Grimm 1996; Jax et al. 1998) and sustainability-oriented Malthusian and neo-Malthusian economists. The birth rate among poor households in tropical regions is frequently identified as the major cause of ecosystem degradation, without attention to the distributional factors and power relations which modify the impacts of demographic growth. This biological focus on population growth has lead to the dangerously misleading conclusion that the poor are the main agents of resource degradation. Much of the evidence suggests that the principal agents of negative environmental change do, in fact, have strong commercial interests, such as cattle ranching and international logging and industrial and large-scale commercial fishing. Most such activities are mobile, sequentially predatory commercial undertakings, backed by powerful political interests and without local roots (Fearnside 1993; Huitric et al. 2002; Armitage 2002; Huitric 2005; Glaser et al. 2003). Despite this, small farmers continue to be blamed for rainforest deforestation, local subsistence users for coastal mangrove deforestation, and coastal artesanal fisherfolk for overfishing. A range of strongly misanthropic and ineffective recommendations such as taxation of expenditures on children (Ehrlich 1971), and prohibitive regulatory approaches to the management of nature, including the forceful removal of resident human populations from the ecosystems they depend on, have resulted from this line of analysis.

At the policy level, the 'pristine nature' mind map has led to the subdivision of biophysical systems into 'pristine' core areas without people, surrounded by buffer zones, the ultimate aim being to keep 'people out of ecosystems' (Diegues 1998; Pretty 2002; Manuel-Navarrete et al. 2004). The idea of isolating pristine ecosystem territory from the human presence in people-free protected areas originated in North America and is inappropriate for the conservation of more densely populated and intensively used ecosystems in most tropical regions (Ghimire and Pimbert 1997; Diegues 2005).

The pristine nature mind map has given rise to conservation strategies which undermine the cultures and livelihoods of poor rural people who typically have little power to defend their interests (Blaikie and Jeanrenaud 1997; Finger-Stich and Ghimire 1997). This is exacerbated by top-down 'command-and-control' policies which marginalise the needs and priorities of ecosystem users and have proven to be both socially dysfunctional and ineffective in terms of biological and ecological outcomes (Brandon and Wells 1992; Ghimire and Pimbert 1997; Glaser et al. 2003).

More recently, the search for 'a better understanding of the ways in which culture evolves and determines ... human behaviour, including humanity's treatment of its life support systems' (Ehrlich 2002, 32) provides greater scope for constructive engagement with those aspects of poverty with degrading influences on nature, as well as those aspects of demographic growth which encourage the development of desirable future trajectories of change (Krause et al. in press).

At the same time, the 'pristine nature and society with anthropogenic drivers' mind map has a definite strength: It provides a clear framework for the quantification of the socially induced eco-physical and bio-geo-chemical processes which potentially undermine sustainable human-nature relations. Concepts such 'carrying capacity' (Daily and Ehrlich 1992) and 'ecological footprint' (Rees 1996), the 'Driving force-Pressure-State-Impact-Response' (DPSIR) framework and the idea of 'systemic throughput' (Daly 1991; 2003) all identify anthropogenic drivers which generate malign changes in the natural environment.

However, the practical application of the concept of anthropogenic driver in ecosystem management, without regard to social and cultural concerns has frequently resulted in non-compliance, non-enforcement and non-implementation of top-down, command-and-control management policies, which are sound from the natural science point of view (Brandon and Wells 1992; Govan et al. 1998; Glaser et al. 2003; Manuel-Navarrete et al. 2004; Schöler 2005). Purely eco-centric mind maps are clearly a major cause of such failures. Their exclusive focus on the 'needs of nature' reduces the social dimension of ecosystem management to the degrading impact of humanity on nature. More recent analyses of the anthropogenic drivers of environmental change identify 'non-linear links' between population and environment dynamics which are affected by the type and quality of social relations (Curran and Agardy 2002). The analysis of the effects of affluence and technological change on human-nature relations has also moderated the exclusive focus on population in the anthropogenic driver's debate (Rosa et al. 2004) and re-kindled the debate on the influence of values and life styles on human-nature relations.

The main strength of the 'pristine-nature and society' mind map is that it supports the quantification of human pressures on the environment. Despite recent improvements, its major weakness remains its exclusion of all but the most rudimentary social and institutional analysis. This omission continues to lie at the root of many unsuccessful, 'socially illiterate' conservation approaches.

The Colonisation of Natural Processes and Societal Metabolism

The term 'societal metabolism' describes 'all material and energy flows associated with human activity, i.e., physical input/output processes between a society and its natural environment' (Grünbühel et al. 2003; Fischer-Kowalski 2004). Deriving its intellectual roots from sources as diverse as Marxian political economy, biology, ecological anthropology and thermodynamic theory (Georgescu Roegen 1971, 1977; Ayres and Simonis 1994), the societal metabolism approach was developed at the Institute for Interdisciplinary Studies in Vienna. Although nature and society are both understood as 'complex autopoietic systems, that is systems with temporal and spatial dynamics dominated by internal processes and self-organisation' (Grünbühel et al. 2003, 55), this approach parallels the anthropogenic drivers in the 'pristine nature and society' mind map (Figure 2) in that it focuses exclusively on the degrading impact of human activities. Thus, societal metabolism is probably best described as an eco-centric systems model. Its merit lies in that it shows that increases in material and energy flows between society and nature derive from transformations in the character of interactions between society and its natural environment, as for example reflected in the transitions from hunter-gather to agrarian and from agrarian to industrial societies. Through its vision of a further transition to a post-industrial society (Voet et al. 2004), the 'societal metabolism' mind map (Figure 3) provides inputs for future scenario development. As changes in socio-cultural preferences and lifestyles are explicitly included in the analysis of societal metabolism changes, the concept of the 'social' is more comprehensive than in the 'pristine nature and society' mind map whose idea of anthropogenic drivers retains a 'black box' mentality in relation to social rationalities and motivations.

The societal metabolism concept is operationalised via material flow analysis (MFA) (Kleijn and Voet 2001). MFA defines and quantifies the physical dimension of human uses of nature as material flows. As with the quantitative models based on the concept of anthropocentric drivers mentioned above, there is no consideration of the social repercussions of changes in the natural environment. These models take into account neither material nor non-material aspects of what nature does for humanity. They ignore nature's delivery of goods and products to humanity as well as its non-material services such as tranquillity and recreational opportunities. The latter contribute to human well-being by maintaining mental and physical health through psychological and physical connectedness to nature[2]). In scientific debate on the management of human-nature relations, the demand to systematically account for the non-material functions of nature for human and societal well-being (Chiesura and de Groot 2003) is only just beginning to be addressed (Reid et al. 2005). However, as noted above, the non-material dimension of human-nature relations has long been a defining characteristic of the deep ecology worldview. It also frequently arises in environmental conflicts ranging from disputes between indigenous movements and natural resources-oriented commercial enterprises (Sethi 1993) to citizens' resistance to the industrialisation of land- and seascapes through wind energy-related construction in Europe.

The quantitative accounting for the degrading effects of socially caused material fluxes on nature is important to determine the eco-physical limits of the human-nature relation at any point in time. It can be misleading, however, if adopted as the sole criteria in the assessment of sustainability in human-nature relations. This is especially pertinent at the local and regional level where natural science-led proposals for sustainable ecosystem management are often at odds with 'local voices' (such as the well-known early Chipko tree-hugging movement in India and numerous similar groups involved in local struggles) which aim to preserve the non-material (and material) functions of nature (Wignaraja 1993; Sethi 1993). Without disputing the primacy of basic (material) human needs, it is important to note that those who argue that the protection of the non-material functions of nature is a luxury for the wealthy usually themselves belong to well-off groups whose economic interests generate ecosystem degradation for poorer and less powerful ecosystem user groups.

Anthropocentric Mind Maps

Anthropocentric mind maps of the human-nature relation define nature either as the product of social and cultural perceptions or in terms of the goods and services nature provides to humanity. Not surprisingly, anthropocentric mind maps involve more complex ideas of the social dimension in ecosystem management than eco-centric mind maps. This

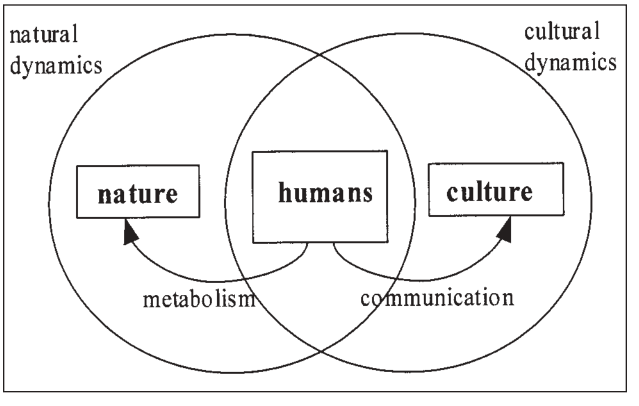

Figure 3. Societal metabolism (adapted from Fisher-Kowalski 2004, 315)

paper differentiates between absolutely and moderately anthropocentric mind maps.

In absolutely anthropocentric mind maps nature is considered as a social construct only. In this view, nature has no objective existence. It exists only through the socio-cultural lense of the observing party. Moderately anthropocentric models subscribe to the underlying world view of 'man dominant over nature' (Capra 1985; Dunlap and Catton 1994; Gelobter 2001) and perceive nature only through its functions in the fulfilment of individual human and collective societal needs.

'Nature Through Society'

The absolutely anthropocentric mind map 'nature through society', which is derived from social constructivism, is located at the 'culture end' of the nature-culture debate. This mind map (Figure 4) suggests that nature has no objective existence, that 'there is no such thing as nature separated from human social processes' (Tester 1991;Westley et al. 2002; Janssen 2002). The ability of social systems to create structures of meaning is here interpreted to mean that nature 'is' only through social perception, through various cultural lenses which generate different virtual realities of 'nature.' In this tradition of thought, the term 'natural' is suspected of obfuscating the ideological content of our knowledge about nature and the power relations within which this content is derived. (Eagleton 1983; Quigley 1999; Darier 1999; Latour 2004).

Luhmann argues that the 'natural order of things' is increasingly irrelevant in modern society. This idea was the basis for the unquestioning acceptance of, and absence of alternatives to the established order of things in earlier, hierarchical societies. Society was conceived as an organic whole where the functions assigned to each individual were essential for both individual and societal existence. As social standing in modern society is increasingly obtained through achieved rather than ascribed criteria, social mobility increases and possible social trajectories multiply. In this context of change, the description of any phenomenon as 'natural' has become suspect of ideological abuse in the interest of powerful social groups (Luhmann 1987, 633). This reminder that the term 'natural' can be used to justify undesirable phenomena such as exploitation and inequity is an important contribution that the 'nature through society' mind map has made to socially sustainable human-nature relations.

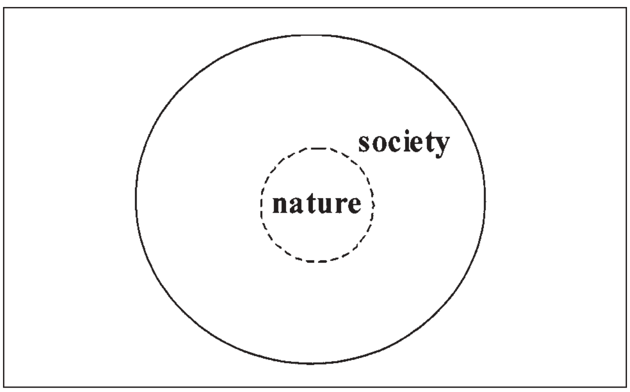

Figure 4. Nature through society.

MacNaghten and Urry (1998) develop this idea further and argue that there is not one nature, but a variety of 'natures' contested as cultural constructs. At its most extreme this can lead to a denial of 'real' objective properties of nature and neglect of 'the causal determinant power of natural effects like resource, waste absorbent and food-production capacities and climatic and atmospheric effects.' (Martell 1994, 178). The denial of the objective existence of nature, which is expressed in this mind map and is implicit in classical sociology, 'forgets' the relevance of nature to continued human life on earth and ignores the role of nature as a formative agent in the development of human society. This blinkered view is clearly dysfunctional and can only hinder interdisciplinary research on human-nature interactions. If nature is seen only as a cultural or scientific construct (Latour 2004), if its real existence is denied, human agency in relation to environmental problems becomes unnecessary and human-nature problems only exist in the eyes of the beholder. Such abuses of the 'nature through society' mind map have done much to hinder interdisciplinary cooperation between natural scientist and sociologists.

When not taken to such extremes, however, the idea of contested natures has been extremely fruitful. As Eden (2001, 83) states "Exploding the rubric of 'nature' thus allows us to examine its power to move us to use, value or protect it but does not negate the noncultural." The assertion that humanity perceives nature through changing social and cultural lenses does not necessarily deny the existence of nature as a real phenomenon, but does allow the analysis of different views and interests in relation to nature. Moderate versions of social constructivism, without denying the physical reality of the ecosystems which make up nature, have inspired the development of collaborative leaning processes and transdisciplinary research methodologies (Duffield et al. 1998; Fontalvo-Herazo 2004; Cundill et al. 2005) which give voice to and connect diverse types of ecosystem-related knowledge. This approach facilitates dialogue and positive interaction between traditional and natural science based knowledge of ecosystems. The appearance of stakeholder analysis in ecosystem management (Overseas Development Administration 1995abc; Grimble and Wellard 1997) and the emergence of new forms of problem-focussed transdisciplinary knowledge about ecosystems and the human-nature relation (Norgaard 1994; Endter-Wada et al. 1998; Meppem and Bourke 1999; Hisschemöller et al. 1998; Köhn and Gowdy 1999; Olsson et al. 2004; Kaplan and McCay 2004) can be traced to this mind map.

Thus, while the concept has created major obstacles for interdisciplinary research, the 'nature as culture' mind map has enabled the analysis of structures of power and exploitation which allow for the pursuit of equity and justice issues without which sustainable ecosystem management is considered elusive by many (Ghimire and Pimbert 1997; Gelobter 2001; Smith and McDonough 2001; Bossel 1999; 2001). Moreover it has drawn attention to the central importance of social learning processes for sustainable human-nature relations in appropriate organisational and institutional environments.

'Nature-For-Humanity'

This mind map (Figure 5) defines nature in terms of the services it provides to human and societal well-being. Nature's role in societal functioning determines the perception of the human-nature relation and of nature herself in this mind map. Humanity is moved centre stage as nature is conceptualized in term of its contribution to human well-being. At the level of the human individual, the focus is on the material (Daily 1997; Constanza et al. 1997a, Grasso 2000), — and more recently also the non-material needs (Reid et al. 2005) of individual human beings and on nature's functions in their fulfilment. The 'nature-for-humanity' mind map supports the idea that nature exists exclusively to serve humanity and that we will continue to be able to dominate nature for our purposes. This approach, also denominated as 'resourcism', has been heavily criticised for ignoring the natural limits to societal use of nature and for confining the importance of ecosystems to their functions in the fulfilment of human and societal needs. Critics point to the dangers inherent in this approach arguing that 'where once we thought endangered species were the problem we now face the loss of entire ecosystems' (Grumbine 1994, 35). Proponents of the nature-for-humanity mind map recommend the development of indicators to avoid such pitfalls. However, in practice, the 'nature for humanity' mind map is often associated with successive cycles of ecosystem degradation with inherent longer-term dangers to human well-being (Holling et al. 2002).

Quantitative input-output models (Leontieff 1986; Turner 2000) represent nature in terms of the goods and services it provides to humanity. Such models connect biological and economic science but 'reduce ecosystems to discrete boxes of resources the yields of which are to be individually maximised' (Berkes and Folke 1998). In view of as yet little understood ecosystem complexity, the focus on maximum sus-

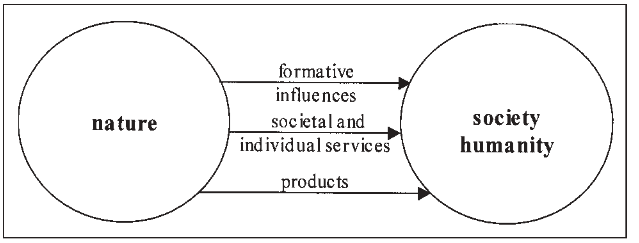

Figure 5. Nature for humanity.

tainable yield at the species level is now generally considered unworkable (Pikitch et al. 2004; Special Issue Marine Ecological Progress Series 2005). It also provides an unsatisfactory, linear and unduly reductionist interface with the non-economic social sciences.

On the positive side, the 'nature-for-humanity' mind map clearly increases the interpretational scope of the social dimension of ecosystem management in important ways. By emphasising nature's contribution to human well-being, it allows for the inclusion of basic human needs, poverty and justice into ecosystem management and opens the way for the comprehensive view of nature's services to humanity. This was, for instance, recently evident in the Millennium Ecosystem Assessment (Reid et al. 2005). It signifies a re-evaluation of the socially insensitive keep people out of ecosystem approaches predominant in conservation cycles but increasingly inappropriate with ever more integrated human-nature relations in the ongoing anthropocene (e.g. Udaya Sekhar 2000; 2003). The 'nature-for-humanity' mind map has contributed to the emergence of integrated sustainability-oriented approaches to ecosystem management which have come to include human well-being as a legitimate and important objective.

Critical voices from among biologists, eco-philosophers, deep ecologists and, more recently, complex systems analysts argue that this mind map's valuation of nature merely in terms of her functions for humans and society is morally indefensible, ecologically short-sighted and lacking the scope to address the mutually formative dynamics of tightly interlinked social-ecological systems.

Interdisciplinary Models

'The natural' — in anthropocentric, and 'the social' — in eco-centric mind maps are portrayed as merely instrumental for their respective primary reference systems. By definition their own dynamics disappear into a 'black box'. The more absolutely eco- and anthropocentric mind maps of human-nature relations assume the complete hierarchical embeddedness of the 'secondary' into the 'primary' system and have little or nothing to say about the embedded 'secondary' systems. The shortcomings of applied approaches such as the pressure-state-impact-response model, which focus on linear cause and effect chains and ignore the interrelated character of human-nature relations, reflect this.

Although, as pointed out in previous sections of this paper, eco- and anthropocentric mind maps support important elements in the management of human-nature relations, they lack the integrative analytical potential necessary for sustainable ecosystem management. A number of more explicitly interdisciplinary models attempt to overcome the simplification and instrumentalisation of the respective disciplinary 'other' common to eco- and anthropocentric mind maps. These models attempt to address ecological, economic and social dimensions of ecosystem management in a balanced manner. In the following section, I explore the implications of various interdisciplinary mind maps for the conceptualisation of the social dimension in the management of ecosystems.

Parallel Spheres

Probably the most common interdisciplinary model encountered in the ecosystems and sustainability management debates is the three-dimensional or three-pillar approach (Figure 6). This generally aims for a balance between ecological, economic and social objectives (Spangenberg 1997; 2000; Enquete-Kommission 1997; Bizer 2000). A fourth, institutional dimension, otherwise subsumed as part of the social dimension, may be added. Under the parallel spheres approach, the social sustainability dimension has suffered from shortcomings in definition and operationalisation which tip the balance between the sustainability dimensions to its disadvantage (Glaser and Diele 2004). Attempts to render social, economic and ecological objectives compatible have had little success under the 'parallel spheres' approach. Some proponents of the parallel spheres approach to sustainable ecosystem management explicitly regard the social as secondary to the environmental dimension (Serageldin 1996, 3). Frequent on-the-ground failures of conservation and environmental policies that prioritise environmental over social objectives (Brandon and Wells 1992; Ghimire and Pimbert, 1997; Govan et al. 1998; Glaser et al. 2003; Manuel-Navarrete et al. 2004; Glaeser et al. 2005; Schöler 2005) have discredited this view. Lehtonen notes that 'distinguishing the 'social' from the 'economic,' the parallel spheres approach, treats the 'economic' as a separate sphere, detached from the social context within which all human activities are embedded.' (Lehtonen 2004, 201). Approaches such as Spangenberg's sustainability triangle or sustainability prism (Spangenberg 1997; 2000) only partially overcome this limitation by introducing interlinkages between spheres.

Raskin et al. (2002) explain the failure of the parallel

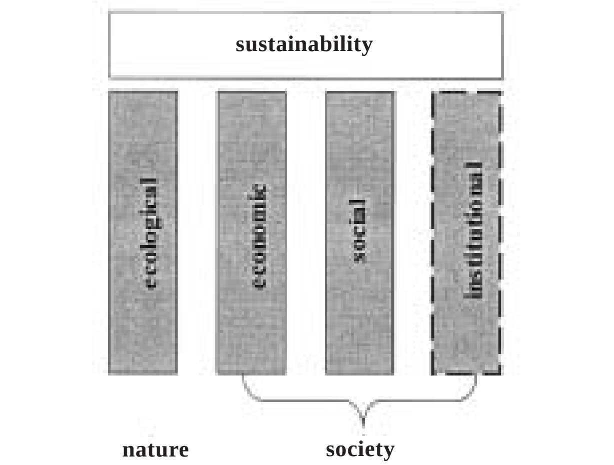

Figure 6. Parallel spheres.

spheres approach to achieve balanced economic, social and ecological change as a consequence of the omission of fundamental social drivers such as values, needs, knowledge, power structures and culture. The 'parallel spheres' mind map was a starting point for the examination of the internal dynamics of subsystems relevant to the analysis of ecosystem sustainability. It draws attention to social system dynamics of relevance to the management of human-nature relations, such as institutional and legal processes (Söderbaum 1994; Torell and Salamanca 2001; Ribot 2001). However, its conceptual separation of economic, social and ecological domains and dynamics falls short of contemporary ecosystem management requirements since it severely inhibits the integrated analysis of human-nature dynamics (Redman 1999; Glaeser 2001).

The Human Ecology Pyramid

Human ecology is an explicitly interdisciplinary research field that focuses on human nature relations. The term 'biological ecology' distinguishes traditional ecology, which considers humanity as a biological species only, from human ecology, which analyses both the cultural and biological determinants of biotic and social structures and processes in conjunction. In pursuit of this objective, the 'father' of human ecology, Robert Park (Park 1936; Teherani-Krönner 1992; Serbser 2004a) developed the concept of a hierarchically structured pyramid of four levels (Figure 7). Nature, at its base, is the ecological foundation upon which society rests. At consecutively higher levels, society is conceptualised as the economic, political and moral order, with the moral order at the apex. The social dimension, here termed the 'cultural superstructure' is supported by a biotic substructure which generates social structures and processes[3]. This 'symbiotic

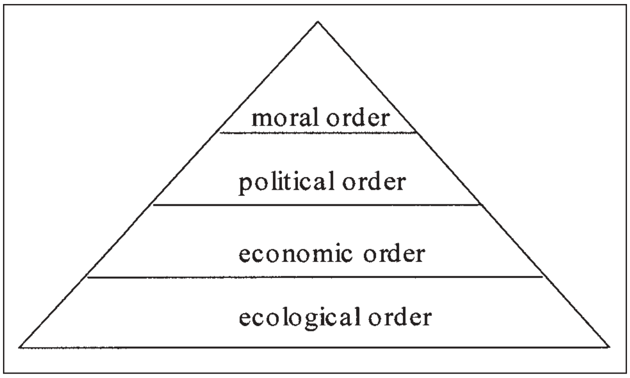

Figure 7. The human ecology pyramid (adapted from Teherani-Kröner, 1992 according to Park 1936)

social order' (Park 1936) is also found among social insects. However, human society is distinguished from animal societies with their symbiotic social orders by its cultural superstructure. Importantly, this cultural superstructure 'imposes itself as an instrument of direction and control upon the biotic superstructure' (Park 1936, 15) and its values, norms and rules control human-nature relations and generate biotic balance and social equilibirum.

Although a main intention behind the human ecology pyramid was to facilitate the analysis of transition processes (Teherani-Krösnner 1992, 28) it is, not surprisingly considering its early origins, a static and mono-causal concept. Its uni-directional postulate that culture controls biological outcomes ignores the eco-physical constraints nature imposes on human society and culture. Today, the assumption underlying this mind map that equilibrium is the ultimate objective of managing social and ecological systems has been replaced by a focus on adaptive change management (Berkes and Folke 1998; Holling and Gunderson 2002). Serbser (2004a, 135) points out that human ecology's early perception of society as an ecological, economic and social construct has gained renewed relevance in the sustainability debate. By explicitly focussing on relations and interlinkages between the biological and the cultural, the human ecology pyramid overcomes the conceptual separation of natural and social domains which is the central limitation of the later 'parallel spheres' mind map. The human ecology pyramid thus laid the conceptual foundations for the analyses of complex systems dynamics which are being developed today[4]. Moreover, by portraying biological outcomes as constrained and directed by cultural norms, the human ecology pyramid draws attention to the transformative potential of changes in values and norms for the human-nature relation. This is being taken up by current approaches such as recent population focussed work (Ehrlich 2002) and global scenario building (Raskin et al. 2002).

The 'Extended Ecological Complex'

The 'extended ecological complex' model (Catton and Dunlap 1978; Dunlap and Catton 1979) aimed to turn nature into a relevant factor in sociological analysis by entering ecological variables into sociological analysis—a feat which classical sociology had hitherto failed to achieve.

Based on Park's social complex (1936) and Duncan's (1959, 1961) 'ecological complex,' the extended ecological complex (Figure 8) provides the analytical foundations for an environmental sociology. Its conceptual framework is designed to investigate the mutual interactions between nature and society, or—in Dunlap and Catton's terminology—between the environmental and the social complexes. The environmental complex disaggregates into the built or human-made environment, the natural environment and the modified environment. The social complex comprises population, technology, culture, social systems and personality (Figure 8). The inclusion of personality in the social complex is an innovative feature. It reflects the bipolar individual and societal character of the social dimension of ecosystem change (Lass and Reusswig 2001; Empacher and Wehling 2002). This allows for analytical attention to social driving forces which originate with human actors at the individual level as well as to social drivers generated at the collective societal level.

Dunlap and Catton's 'extended ecological complex' was designed to analyse the social causes of environmental dynamics and also the environmental causes of social change. It was envisaged as forming 'a dynamic, processual flowing complex...the whole complex and its parts constantly shifting

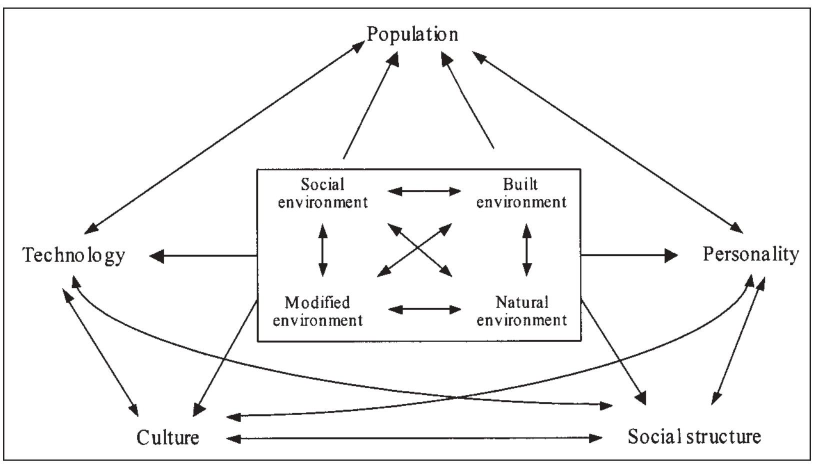

Figure 8. The extended ecological complex (Dunlap and Catton 1979)

and changing in character' (Martell 1994, 168). By allowing for mutually formative interactions between its constituent components it is 'an antidote to mono-causal and environmentally insensitive analyses' (Martell 1994). The 'extended ecological complex' is more dynamic and conceptually more sophisticated than all models previously described in this paper. Its explicit assumption that human societies are ecosystem-dependent, and that nature is a causal factor in the development of societal structures and dynamics (Dunlap and Catton 1979), represents an important step beyond the limiting boundaries of classic sociological analysis. However, perhaps because of its overall complexity, or because of the inherent threat it poses to classical sociology by including nature as an explanatory factor for social dynamics, the 'extended ecological complex' failed to gain acceptance as a major mind map in its time.

The Bio-Economy Model

The bio-economy model (Figure 9) appears like a more complex version of the eco-centric 'society-within-nature' mind map. It conceptualises 'three concentric circles, the environment circumscribing the social dimension, and the economic sphere constituting the innermost circle. This reflects the idea that economic activities should be in the service of all human beings while at the same time safeguarding the biophysical systems necessary for human existence' (Lehtonen 2004, 201). Here, the social is in command of the economic, but both are subject to environmental constraints. Although absolute at any point in time, environmental constraints are seen as responsive to changes in knowledge and technology.

The bio-economy concept has strong normative underpinnings. It proposes what should be, rather than constructing an explanatory model of reality 'grounded' in empirical observations (Glaser and Strauss 1967; Hukkinen 2003). Since

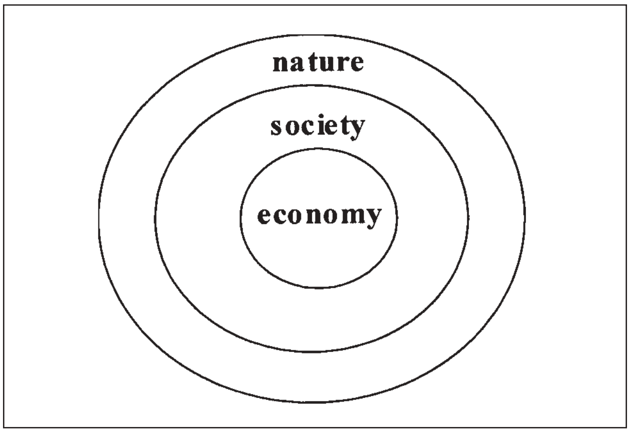

Figure 9. The bio-economy.

norms are needed for planning (Raskin et al. 2002) such normative conceptual models may serve as a policy-planning guide.

Although the bio-economy model resembles eco-centric mind maps, it differs from these in its emphasis on human needs and societal goals as valid objectives of ecosystem management. It adopts the view that while human existence and society are circumscribed by the physical limits of nature and should respect these limits, at the same time nature is, and should be responsive to human needs. The bio-economy model thus combines the more moderate features of eco- and anthropocentric mind maps. This allows for the interdisciplinary determination of ecosystem management aims. However, as this mind map retains the separate, parallel spheres approach, it fails to enable the analysis of the cross-sphere linkages which constitute the core of human-nature relations.

Complex Systems Models

Complex systems possess an internal structure of many different processes, subsystems and interconnections in which subsystems assume specific functions (Machlis and Force 1997; Bossel 2001). Systems theory is the 'science of the integration of parts' (Holling 1998) which has emerged as part of 'post-normal' science to address problems such as low predictability, uncertainty and surprise (Funtowicz and Ravetz 1991; Funtowicz and Ravetz 1994; Funtowicz et al. 1998; Kay et al. 1999). Factors such as uncertainty, non-linear feedback, cross-scale interactions, self-organisation and emergence (Trosper 2005) cause complexity in social and ecological systems. Models of complex linked systems attempt to analyse human-nature dynamics by concentrating on intersystem linkages and combining these with internal subsystem dynamics. The systems approach has important intellectual roots in the idea of co-evolution (Norgaard 1994; Berkes and Folke 2002; Bossel 2001).

Low predictability and the high incidence of surprise have led to an emphasis on adaptability as a necessary system characteristic and on resilience management as an inter- and transdisciplinary strategy (Holling 1998; Walker et al. 2002, Adger et al. 2005)[5].

The different types and dimensions of scale involved in human-nature relations are central to complex systems approaches. Ecologists' scale ranges from the genetic, via species, ecosystems and landscapes to the planetary; geographers emphasize spatial scales starting well above the genetic level; historical ecologists look at temporal scale; political scientists at institutional and administrative definitions of scale, and sociologists at interactions between scales (Cundill et al. 2005). The concept of nested systems, which is taking root in complex systems theory (Force et al. 1995; Bossel 1999; 2001; Kay et al. 1999; Berkes and Folke 2002), addresses some of the issues that arise from differences in scale. Interdisciplinary agreement on scale — as on a range of other issues — appears, however, only to be possible in particular, problem-specific contexts (Pritchard and Sanderson 2002; Heemskerk et al. 2003). More general inter- and transdisciplinary agreement on scale is made difficult by ambiguities in defining system boundaries, which lead to problems in distinguishing between internal, external and cross-scale system dynamics (Cumming and Collier 2005).

In the following, two major approaches to complex systems are outlined with a focus on their achievements in the conceptualisation of the social dimension in ecosystem management. Omitting system scales below the level of the individual gene (i.e. DNA analysis) for the time being, our debate of social-ecological dynamics concenrates on localities, regions and the planetary level.

Subsystems for Sustainable Development

The mind map in Figure 10 explicitly addresses the dynamics of the anthroposphere, i.e. the sphere that is affected by and affects human society, as part of an 'assemblage of nested and linked subsystems (Bossel 1999, 40). It is assumed that '...human society is a complex adaptive system, embedded in another complex adaptive system — the natural environment — on which it depends for support' (ibid, 2). Six minor subsystems that contribute to total system viability are aggregated into three major subsystems:

- the human system with
  - individual development,
  - social system,
  - government system;
- the support system with
  - economic system,
  - infrastructure system;
- the natural system with
  - environment and resource system.

The human, support and natural system are each endowed with a stock of vital assets: human, structural and natural capital. In the tradition of engineering approaches to systems theory, viability and performance conditions are then proposed by identifying the major needed system properties — or in Bossel's terminology 'orientors.' For autonomous, self-organizing systems, system viability, sustainability and performance are seen to depend on:

1) existence (is the system compatible with and able to exist in its environment?),
2) effectiveness (is the system effective and efficient?),
3) freedom of action (is the system able to respond as needed?),
4) security (is the system secure, safe and stable?),
5) adaptability (can the system adapt to new challenges?),
6) co-existence (is the system compatible with interacting subsystems?).

For self-reproducing (autopoietic), sentient and conscious systems, these conditions are complemented by:

7) reproduction (is the system able to reproduce at sufficient rates?)
8) psychological needs (is the system compatible with psychological needs and culture?) (Bossel 1999, 25-40; Bossel 2001).

In the 'subsystems for sustainable development' mind map (Figure 10), the social dimension is located in the human and support systems as well as in the relations between subsystems. With material from psychology, religion and from the study of artificial life, Bossel (1978; 1998; 1999) shows that his orientors, which are applicable to all system types, directly reflect central human survival and well-being concerns. He concludes that 'values are not subjective inventions of the human mind but are basic system requirements emerging from a system's interaction with its environment' (Bossel 1999, 37). Bossel's approach to complex systems thus provides a theoretical basis for the derivation of social sustainability conditions such as security, freedom and cultural appropriateness which hitherto were generally regarded

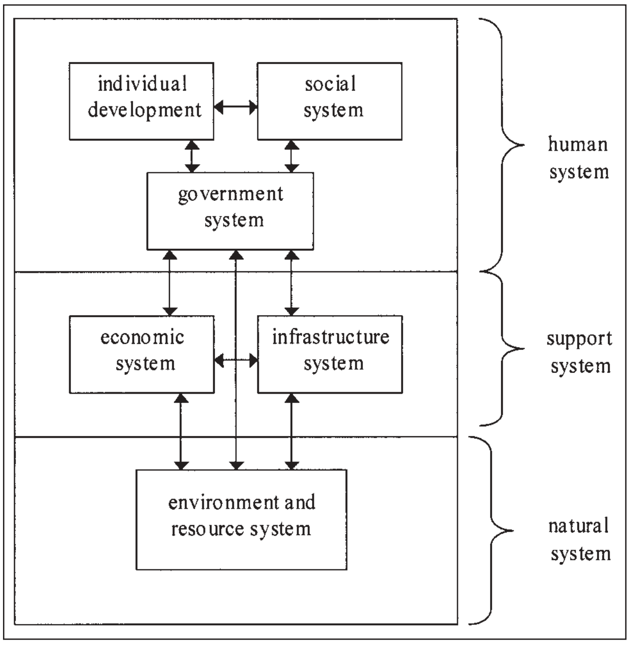

Figure 10. Subsystems for sustainable development. Source: Bossell 1999, 16.

— and dismissed by some — as exclusively normative. This is important theoretical groundwork for the operationalisation of the social dimension in human-nature relations. An empirical comparison of Bossel's system approach with a participatory approach to developing indicators of sustainable coastal mangrove management (Fontalvo-Herazo 2004; Fontalvo-Herazo et al. under review) shows that almost all indicators prioritised in a participatory process by stakeholders were also identified through Bossel's system-based approach to indicator development. The latter, however, also delivered additional indicators on aspects which had been unimportant to the stakeholders consulted in the empirical exercise. Bossel's 'engineering approach to complex system analysis of human-nature relations thus holds considerable potential for the comprehensive and systematic operationalisation and monitoring of the social (and other) dimensions of ecosystem management.

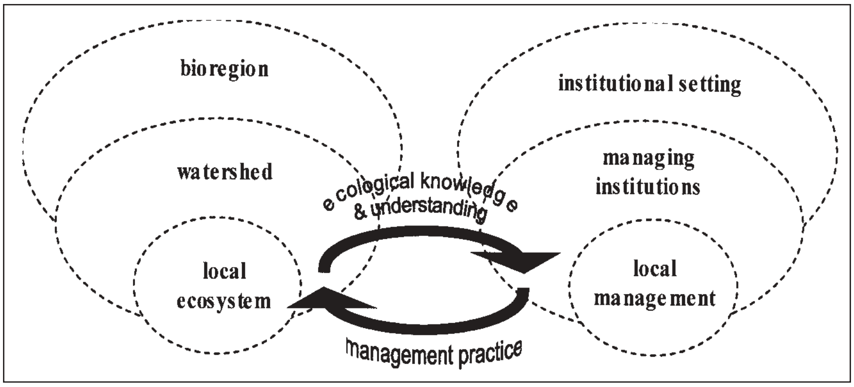

Figure 11. Social-ecological systems. Source: Berkes and Folke 2002, 125.

The engineering approach is considerably weaker in its ability to capture dynamic change processes. Bossel suggests that if systemic learning and adaptation processes are slower than the pace of system response, system viability is under threat. This could be assessed by comparing the rates at which system threats develop to system response rates via non-dimensional Biesot indicators (Biesot 1997). These measure the ratio of system change to system response/respite time and will indicate danger if the indicator value is smaller than one (Bossel 1999; 2001). Such indicators have, however, not been developed in practice possibly because of the non-linearity and low predictability of such systemic rates. Monitoring based on indicator systems within the framework of Bossel's systems engineering approach may partly capture dynamic change through long time series. However, monitoring current and past systemic states is clearly of limited use to assess possible future trajectories of change. Thus, while monitoring and analysis are central for operationalising the social dimension of human-nature relations, not least by building stakeholder capacity to work towards desirable change (Fontalvo-Herazo et al. under review), their ability to capture or foresee systemic change is low. Alternative approaches to complex systems have developed more promising ways to investigate and manage dynamic change in human-nature systems.

Social-ecological Systems and the Adaptive Cycle

Social-ecological systems theory's point of departure is that in order to manage ecosystems sustainably the combined functioning of the social-ecological system needs to be understood. This mind map (Gunderson and Holling 1998; 2002; Berkes and Folke 1998; Berkes et al. 2003) views human, societal and natural dynamics as part of one integrated system in which social-ecological interconnections are prominent and in which any delineation between social and natural systems is artificial and arbitrary (Berkes and Folke 2002). The quest of social-ecological systems theory is '... to understand the source and the role of change in systems, particularly the kinds of changes that are transforming, in systems that are adaptive. Economic, ecological and social changes occurring at different speeds and spatial scales are the target of the analysis of adaptive change' (Holling et al. 2002, 5). The social dimension is thus an integral and inseparable, co-evolving part of the social-ecological system.

Figure 11 is a visual representation of the social-ecological systems concept, which emphasizes the central role of social learning. The components of the nested hierarchical structure of ecological and social-institutional systems are connected through ecological knowledge and understanding, which then translates into management practices. A variety of other drivers of social-ecological change are possible.

In the debate on sustainable ecosystem management, the social-ecological systems approach searches for system configurations which produce desirable system states. The core of its approach to management is resilience. The resilience of social-ecological systems resides in self-reinforcing mechanisms which inhibit shifts into undesirable system configurations (Folke et al. 1998; Gunderson and Holling 2002), 'maintaining the capacity of the system to cope with whatever the future brings without the system changing in undesirable ways' (Walker et al. 2002). Originally an ecological term (Holling 1973), more recent interpretations of social-ecological resilience integrate natural and social dimensions (Scoones 1999; Peterson 2000; Adger et al. 2005). The increasingly clear focus on social mechanisms in this debate has derived inspiration from the poverty and development debate. Here, societal resilience and adaptability are coming to be considered central for reducing people's vulnerability to poverty (Coulthard 2005). Resilience management has here turned into a common denominator for the integrated management of social-ecological systems under conditions of uncertainty (Adger et al. 2005; Krause et al. in press). In a clear move beyond earlier ideas of system control, resilience management is seen as 'learning to live with systems rather than control them' (Walker et al. 2002). The social-ecological system mind map maintains the focus on human well-being, which the 'nature for humanity' mind map contributed to the social dimension of ecosystem management, without falling into the latter's trap of ignoring natural resource dynamics and assuming human control over nature.

Resilience management relies on the iterative combination of scientific and other forms of knowledge (Funtowicz et al. 2002; Rotmans and van Asselt 2002) to determine the sources of systemic resilience so that promising courses of action and points of intervention can be identified. The need for these different types of knowledge and for public legitimacy renders participatory processes indispensable (Pritchard et al. 2000; Schmidt 2000). Scenario development in which social participation and social legitimation are central is now a favoured tool in resilience management (Walker et al. 2002; Castella et al. 2005; Krause et al. in press).

A central concept to explain change in the social-ecological systems approach is the adaptive renewal cycle (Figure 12). It was originally developed to explain the biological dynamics of ecosystems, but now serves as a general model of dynamic change in the social-ecological systems debate. Under this concept, ecological, economic and social change passes through successive four-phase cycles of

1) rapid growth and exploitation (r-phase), leading to a longer phase of

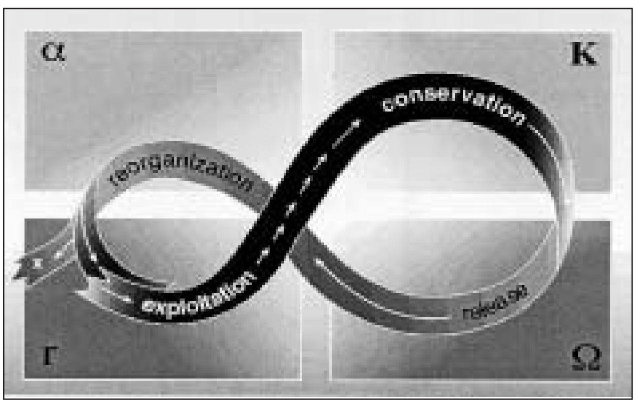

Figure 12. The adaptive renewal cycle.

2) accumulation, monopolisation and conservation of structure (K-phase), followed by
3) rapid breakdown or 'release' (Ω-phase) and eventually
4) renewal and re-organisation (α-phase)

(Holling and Sanderson 1996; Holling and Gunderson 2002; Scheffer et al. 2002).

Social-ecological system cycles are seen as nested within each other at different scales and moving at different speeds with varying phase lengths and cross-scale interferences. With the theory of nested adaptive cycles (Holling and Gunderson 2002), the social-ecological systems school of thought proposes a cross-scale, interdisciplinary and dynamic concept to explain discontinuous non-linear change. The aim is 'to integrate realistic ecological dynamics with forward-looking human behaviour' (Westley et al. 2002). The adaptive renewal cycle has been used to explain evolutionary change in ecology (Holling 1973; 1986), to analyse economic change and business cycles (Schumpeter 1939; Chavas 1999; Westley et al. 2002) and to trace the origins of cycles of development and destruction in human civilisations (Redman 1999).

Although it does explain long-term patterns of change in many different systems, the capacity of the adaptive renewal cycle concept to predict sudden system change is limited. In a recent critique, Cumming and Collier (2005) distinguish five alternative metamodels to analyse different types of social-ecological systems dynamics — and identify the need for more.

With the adaptive renewal cycle, the social-ecological systems approach imports a biological concept into systems theory and applies it to other dynamics (institutions, markets, societies). Such universal approaches can lead to undue reductionism. The underlying driving force of the adaptive renewal cycle is competition. This builds on the ideas of Charles Darwin about nature, of Adam Smith about economic life and of Herbert Spencer about the evolution of human societies. The assumption that humanity, along with all other forms of life, is invariably propelled by competition pushes other potential system drivers such as cooperation, self-sacrifice, community-orientation or love (Hosang et al. 2005) into the background. It also neglects the human capacity for reflection and value change. A clear weakness of the adaptive cycle model is that it views humanity as 'being driven' rather than as capable of reflection and adaptation, i.e. of 'driving.' The adaptive renewal cycle implies that, subject to delays, surprises, cross-scale interference and a range of other variables, competition will invariably prevail. Successive phases of growth and exploitation (r), conservation (K), rapid breakdown(Ω) and renewal(α) are thus pre-determined. This is a teleological conclusion, strikingly similar to the one that Marxism fell victim to. It denies the human option to choose values and priorities other than competition. This seriously limits conceptual scope for analysing the social dynamics of change in values and culture.

Without explicitly criticising the adaptive renewal cycle along the above lines, the more recent focus of social-ecological system analysis on resilience management moderates its bias towards competition through participatory scenario construction (Walker et al. 2002; Krause et al. in press). Here, stakeholder participation can modify assumptions, such as that of competition as the major system driver, in their specific context. Participatory resilience management thus has considerable potential to capacitate social processes towards positive adaptive change and increased viability of social-ecological systems. Values and norms, human reflexivity and collective learning, features absent from the rather deterministic and teleological adaptive renewal cycle, have gained prominence in this newer branch of social-ecological system analysis and opens new and promising paths towards operationalising the social dimension of ecosystem management.

Conclusions and Outlook

The conceptualisation of humanity's unique position as both a species in the web of life and as social and cultural, self-reflective and moral beings is a major challenge in the pursuit of sustainable human-nature relations. Although the diversity of interpretations of the social dimension in ecosystem management presented in this article follows a certain chronological order which illustrates developments over time, it also shows a continuing lack of consensus on the question of what the social dimension to the management of nature and its ecosystem components actually consists of. This article has explored major mind maps of the human-nature relation in terms of their theoretical underpinnings and their potentials to define the social dimension of ecosystem management in ways which maximise the chances of sustainable outcomes. Table 1 summarizes the major arguments.

Table 1. Human-nature mind maps and the social dimensions of ecosystem management

	Weak points	Strengths
ECOCENTRIC		
Represent social needs as subordinate to the requirements of nature.	Positive social potential in the human-nature relation is seen as confined to 'traditional' populations which are further marginalised through socially insensitive prescriptions. Underpins the 'keep people out of ecosystems' approach. Undermines the livelihoods of ecosystem-reliant populations by top-down management which sees humans as mere predators. An insufficient and dysfunctional reduction of the social dimension of ecosystem management.	Its recognition of the embeddedness of humanity in nature provides the essential conceptual background to address the effect of social values and culture on human-nature relations. The anthropogenic driver concept provides the foundation for the quantification of the eco-physical limits to the human-nature relation.
ANTHROPOCENTRIC		
Define nature through a social lens: as the product of social and cultural perceptions or in terms of the goods and services it delivers to humanity.	Where nature is seen only as a cultural construct it can by definition not be under threat. This — extreme — constructionist view of nature, and reduction of everything to 'the social' impedes cooperation between natural and social scientists in ecosystem management. Some anthropocentric mind maps ignore or oversimplify the bio-geo-physical limits to the human use of nature and thus contribute to ecosystem degradation.	The social aspects of ecosystem management this mind map produces such as poverty, basic needs fulfilment and quality of life have put human and societal well-being onto the ecosystem management agenda. Stakeholder analysis, issues of power and exploitation, equity and justice and new forms of problem-focussed transdisciplinary knowledge generation in ecosystem management are rooted in anthropocentric mind maps.
INTERDISCIPLINARY		
Attempt to address ecological, economic and social dimensions of ecosystem management, in a balanced way.	The separation of social, economic and ecological spheres inhibits the integrated analysis of human-nature relations. Despite attempts at balanced treatment, interdisciplinary mind maps such as 'parallel spheres' are associated with an inadequate treatment of the social dimensions of nature management and have thus caused ecologically sound ecosystem management approaches to fail for social reasons.	Give scope for the analysis of social variables such as institutional and legal processes in ecosystem management. Some (the 'bio-economy') combine moderate aspects of eco- and anthropocentric mind maps which supports the interdisciplinary determination of management aims. Others ('human ecology pyramid' & 'extended ecological complex') prepare the way for complex system analysis by focussing on relations between social, economic and ecological dimensions.
COMPLEX SYSTEMS		
Focus on intra- and intersystem dynamics of complex and integrated whole systems at various temporal, institutional and spatial scales.	Uncertainty, non-linear feedback, cross-scale interactions, self-organisation and emergence are seen to cause complexity in social-ecological systems. These concepts require further refinement in order to qualify the blanket claims of low predictability and surprise. The adaptive cycle as the major model of change views humanity as 'being driven' rather than as capable of reflection and adaptation and does not explain all types of change in social ecological systems.	The 'engineering approach' provides a theoretical basis for the comprehensive conceptualization of 'the social' in human-nature relations. This is essential for monitoring purposes. The 'dynamic approach' strengthens underlies resilience management. Scenario development allows for transdisciplinary knowledge generation to strengthen system adaptability.

All these mind maps possess a certain validity. Indeed, the search for a universal framework may actually be inconsistent with the idea that human and environmental systems are situated within particular historical, institutional, cultural and economic contexts and follow regionally specific trajectories of change (Norgaard 1994; Hukkinen 2003; Lehtonen 2004; Reid et al. 2005). It is thus not a question of some mind maps being more 'correct' than others. Rather the aim of this article has been to show how mind maps differ in the ease of interdisciplinary linkages that they offer, and in their potential to operationalise the 'social' in ways which are conducive to sustainable human-nature relations. It stands to reason that the relevance of any given mind map can increase or decrease at particular junctions of history and in general is context-dependent.

What is constant however is the need to recognise the central importance of the social dimension in ecosystem management. Recent analyses of participatory planning approaches to ecosystem management have shown that social objectives feature strongly not only among local ecosystem users, but also among other stakeholders such as researchers and administrators who are not directly affected in their own livelihoods. As human-nature links in the anthropocene continue to intensify and diversify, the importance of the social dimension for our sustainable future(s) grows faster than that of the ecological-environmental and of purely economic dimensions (Duffield et al. 1998; Parkins et al. 2001; Fontalvo-Herazo 2004).

The construction of social indicators, rooted in locally specific historical, social, economic and ecosystem contexts, is thus of growing importance in ecosystem management. Good foundations for a more universal, analytical framework for social-ecological system monitoring have been laid by Bossel. An indicator-based monitoring framework along the universal lines suggested by Bossel provides the structure and comprehensiveness required for the treatment of the social dimensions of ecosystem management which has often been lacking in the past. Social indicators should incorporate the richness and diversity of social-ecological dynamics. To achieve this, the transdisciplinary and participatory methods for scenario development and simulation which social-ecological systems analysis has recently emphasized are essential.

Within the social sphere, Kurt and Wehrspaun (2001) identify a chronic 'cultural deficit' in contemporary sustainability discussions. This omission has recently been addressed by academics and practitioners in the ecosystem management field. Their focus on social learning and on communities of practice for environmental learning and decision-making aims to facilitate desirable change and to strengthen social-ecological resilience (Vickers 1987; Blackmore 2004; 2005; MRAG 2005).

The development of relevant research practice in the human-nature complex is underway and the social dimension in ecosystem management is increasingly an integral and inseparable part of this (Neis et al. 1999; Berkes and Folke 2002; Gadgil et al. 2003; Brown et al. 2003; Terer et al. 2004; Reid et al. 2005). The increased focus in recent years on the need to transform values and institutions in order to visualize and achieve desirable future scenarios of human-nature relations, and then to increase system resilience, is in evidence at the planetary level (Raskin et al. 2002) and at the local level. As an example of the latter, the NGO Care (2005) aims to improve the resilience of households, combining this originally ecological concept with participatory and empowering methods (Coulthard 2005). Temporary learning platforms (Olsson et al. 2004a,b) and environmental education processes (Macer 2003; Maekawa and Macer 2005), which lead to the identification of alternative trajectories of change via participatory narrative scenarios, are being increasingly supported by theory (Kay et al. 1999) and realized in practice (Alcamo 2001; Walker et al. 2002; Glaeser 2005ab).

The dysfunctional conceptual separation of social, economic and ecological domains in eco-centric, anthropocentric and many interdisciplinary mind maps still prevents many of those involved in ecosystem-related research and management from perceiving the potential of these developments. With this review I have shown that a withdrawal into disciplinary or separate parallel sphere approaches is the wrong direction for any scientific endeavour of contemporary societal relevance. Complex systems mind maps already provide major elements of the comprehensive theoretical foundation which is required to conceptualise social-ecological systems and steer their management. They permit integrative analyses with the participation of system stakeholders in transformative and adaptive transdisciplinary work. Their development is in its infancy but appears to be aiming in the right direction.

Endnotes

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2. Thus nature can be seen as partially fulfilling to the basic human need for 'home' (*Heimat*). As part of this debate, Inhetveen (2004) discusses the neglected relation between external nature and the human body.
3. Park's human ecology pyramid was first thus denominated and visualised by Teherani-Krönner (1992).
4. See section 2.4 of this paper and the online Journal *Ecology and Society* for further examples.
5. I define transdisciplinarity as cooperation between two or more academic disciplines which is combined with the active participation of non-academic system stakeholders in the generation of knowledge.

Acknowledgements

The research was financed by the German Federal Ministry for Education, Science, Research and Technology (BMBF) as part of the programme 'Research Focus on the Ecology of Tropical Coastal Areas: Mangrove Management and Dynamics' (No 03F0154A). This is MADAM publication No 93. Thanks to Gesche Krause for comments on an early draft, to Milena Arias-Schreiber for supporting the literature search and dealing with the vicissitudes of bibliography and graphics, and to Andrew Halliday for valuable language editing and comments. Lance Gunderson and one anonymous reviewer provided valuable opinions and hints on the penultimate version of the article. Responsibility rests, as always, with the author.

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